Active Microstrip Log Periodic Antenna

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Abstract--This paper describes two different configurations of integration active devices into log periodic antenna (LPA). The first configuration involves the integration of a single amplifier at the input feed line of a five element log periodic antenna (LPA). The second configuration involves the integration of an amplifier in the middle of the five elements LPA. Integrating an amplifier in front of an array introduces signal gain without reducing bandwidth. Integrating an amplifier in the middle of the feed line appears to offer some potential increase in the bandwidth and introduces additional gain for the array, but it also introduces a negative gain slope vs. frequency.

1. INTRODUCTION

Active integrated antennas receive a great deal of attention because they can reduce the size, weight, cost of the transceiver system and minimizes the connection losses. Due to the mature technology of microwave integrated circuit (MIC) and monolithic microwave integrated circuit (MMIC), the active integrated antenna become an area of growing interest in recent years. Active integrated antennas have many potential application in wireless communications such as low cost and compact transceivers, detectors and sensors. Various antennas have been integrated into active devices that can be classified into oscillator type [1], amplifier type [2,3]and frequency conversion type[6,7].

A compact amplifier integrated antenna was reported by Robert et-al [2]. The transistor was directly integrated onto a microstrip patch antenna. An extra 8 dB gain was obtained at 1.68 GHz. A novel highly compact low noise amplifier was reported by Ormiston et-al [3]. This active integrated antenna provided a gain between 12 and 24 dB referred to passive at 1.35 GHz. Wu and Chang [4] described the configuration of dual FET active patch antenna element arrays for quasi-optical power combining. The circuit uses two FET's that symmetrically load a split patch antenna. An active microstrip patch antenna using an amplifying circuit was reported by An et-al [5]. In this configuration two substrate layers with a ground plane in the middle were used. The microstrip antenna was built on one side of the ground plane and the amplifier was on the other side. The antenna was connected to the amplifier with a coupling probe through the ground plane. An increase of 24% in bandwidth in terms of transferred power gain was reported and at the same time the input signal was amplified

Ma et-al [6] investigated active antennas, which were implemented to act as direct conversion receivers. This active antenna can be applied for Doppler frequency detection, I and Q demodulation and direction finding. Their low power consumption and cheap manufacturing cost make this antenna suitable for short distance communication. An active integrated antenna with simultaneous transmit – receive operation was developed by Cryan and Hall [7]. The active antenna consists of a square microstrip patch antenna orthogonally connected to an oscillator and a receiving amplifier. Isolation of more than 45 dB between transmit and received was reported.

2. ACTIVE LOG PERIODIC ANTENNA (LPA) CONFIGURATION

2.1 Integration of amplifier at the input feed of LPA

This configuration is the simplest, where a single amplifier is integrated at the input of the LPA. The amplifier is biased with a voltage of 8.5 V with 40 mA biasing current. The dc blocking capacitor had to be put in front to block the dc from going into the measurement system. Figure 1(a) shows the configuration schematically, as used for circuit modeling. The layout of this configuration is shown in figure 1(b).

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The single element of the patch is scaled log periodically with scaling factor of 1.05. Each individual antenna and active device has an individual S_{11} parameter data file. The S Parameter data is exported to the schematic diagram as shown in figure 1(a). The distance between element (m) and element (m+1) is determined according to the next higher frequency element of the antenna. The input looking into the next higher frequency must be high impedance before the next element (m+1) is connected to the schematic diagram. In this model the distance between two patches is not necessarily half wavelength and varying log periodically. The microstrip antenna feed line is a quarter wavelength long. This value is scaled log periodically.

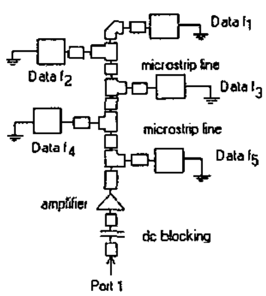
The inset feed distance of the microstrip antenna is chosen for 50 ohm input impedance and it is scaled log periodically. This model can be used for any element of log periodic patch antenna. The design of a quasi log periodic microstrip antenna can be carried out as follows:

(a) Choose the first resonance frequency and scale it log periodically for the subsequent resonance frequencies.

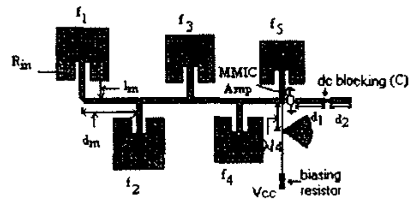
(b) Calculate the patch dimension (W=L) for a square patch antenna and the inset feed dimensions for input impedance of 50 ohm at resonance and scale log periodically for the next patch.

(c) The distances between the branch lines are determined so that the input impedance looking into the next higher frequency is high impedance.

(d) The amplifier is connected at the input of the feed line of the LPA



(a) circuit modeling

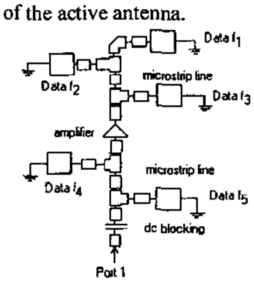


(b) layout of active integrated antenna

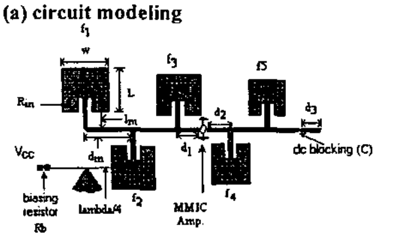
Figure 1 Circuit modeling and layout of the integration of the amplifier at the input feed

2.2 Integration of amplifier in the middle of LPA

The integration of an amplifier in the middle of a five element LPA is shown in figure 2. The amplifier is in the middle of the antenna between the third and fourth patches. In this design the first three elements can be considered as the passive design. After placing the amplifier at the input of the third patch, the fourth element is considered as an active element design. The procedure to design for the fourth element is similar to the design of the passive element. At frequency f_4 and at the point of attachment of the fourth patch element, the input impedance to the amplifier should be high impedance. Therefore the distance d_2 is adjusted to make that impedance as high as possible. The design process continues for the next element Figure 2 (a) shows the circuit modeling and figure 2 (b) shows the layout of the active antenna.



(a) circuit modeling



(b) layout of active integrated antenna

Figure 2. Circuit modeling and layout of integration of amplifier in the middle of LPA

Calculation of design parameters for square patch microstrip antenna is shown in Table 1. The substrate used is FR4 with dielectric constant of 4.7 and height of 1.6 mm. The scaling factor τ = 1.05. The loss tangent of material is 0.019

Table 1 Design parameters for log periodic antenna with scaling factor of 1.05

Data	Freq. (GHz)	W=L (mm)	Quarter wave Length (mm)	R_{in} (50Ω) (mm)
f_1	2.73	25.34	14.40	8.20
f_2	2.87	24.13	13.70	7.80
f_3	3.01	22.98	13.04	7.50
f_4	3.16	21.89	12.45	7.20
f_5	3.32	20.84	11.83	6.90

3. RESULT AND DISCUSSION

The result of active log periodic antenna has been discussed in term of bandwidth response, radiation pattern characteristic, cross polar isolation and gain relative to dipole and passive element for each configuration.

3.1 Integration of amplifier at the input feed line of LPA

(i). Bandwidth response

The input return loss response of this five element active LPA integrating with amplifier at the input feed of the antenna is shown in figure 3. The bandwidth of the antenna is 37% from the measurement and 28 % from simulation result. The simulation results give a good approximation for the measurement even though the frequency has been shifted slightly from the simulation result.

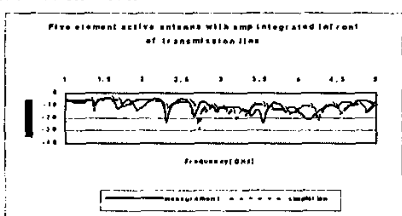


Figure 3 Input return loss

(ii). Cross-polar isolation

The co- and cross-polar responses for this LPA are shown in figure 4. In this measurement result the cross-polar isolation is between 10 and 30 dB for a band of frequency from 2.5 to 3.6 GHz. The cross-polar isolation is more than 30 dB at frequency 2.75 GHz. At 3.4 GHz the cross-polar isolation is minimum.

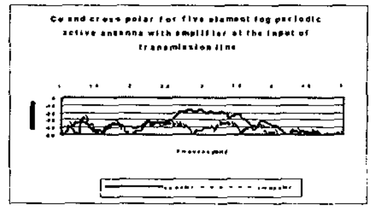


Figure 4. S_{21} response for Active LPA

(iii) Comparison with passive LPA

The comparison between active and passive five element LPAs is shown in figure 5. The gain of the active antenna varies from 5 to 9 dB relative to the passive antenna. At frequency 2.5 GHz the gain is nearly 7 dB. The gain is steadily constant at frequency 2.6 GHz to 3.4 GHz. The lowest gain is at 3.35 GHz where the relative gain of the active antenna is 5 dB. The BW from this measurement is nearly 38% with a centre frequency of 3.1 GHz. The response from the active antenna follows the response from the passive antenna with the same fluctuation

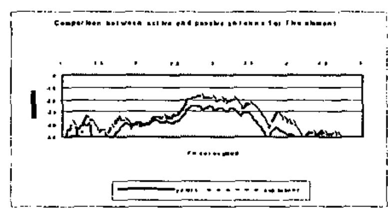


Figure 5 S_{21} response relative to passive LPA

(iv). Radiation pattern characteristics

The radiation pattern is in the broadside direction. In the H plane, the radiation pattern remains nearly the same over the entire BW. However in the E Plane the radiation pattern varies with frequency. The HPBW for the E plane is smaller than for the H plane. At frequency 2.55 GHz the cross-polar isolation for E and H Plane is only 8 dB. The HPBW for E Plane is 30°, which is tilting to the right from the broadside direction and 60° for H Plane. The radiation pattern at middle frequency 3.05 GHz has a cross polar isolation of 25 dB for E Plane and 30 dB for H Plane. At frequency 3.50 GHz the cross-polar isolation is 20 dB for E Plane and 21 dB for H Plane. The HPBW at this frequency is 40° for E Plane and 60° for H Plane.

3.2 Integration of amplifier in the middle of amplifier

(i). Bandwidth response

The input return loss from measurement and simulation is shown in figure 6. The BW of this antenna at 6 dB return loss is 27% from measurement and 31% from simulation. The return loss is lower at the middle because of the effect of amplifier integration.

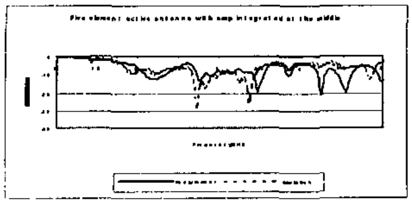


Figure 6. Input return Loss

(ii). Cross-polar isolation

Figure 7 shows the co- and cross-polar responses for this configuration. The co- polar response indicates a 3 dB gain of 0.7 GHz centred on 2.95 GHz. The cross-polar isolation is around 20 dB or more over that frequency range.

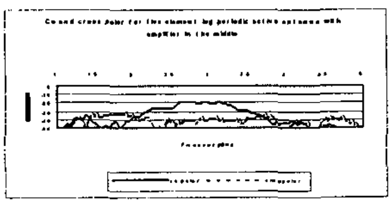


Figure 7 Cross polar isolation

(iii). Comparison with passive LPA

The comparison between the passive and active antenna is shown in figure 8. The active antenna has a gain of 10 dB relative to the passive LPA. From 2.6 to 3.2 GHz, the gain is nearly 10 dB relative to the passive antenna. This is because the amplifier has increased the signal at the lower frequency.

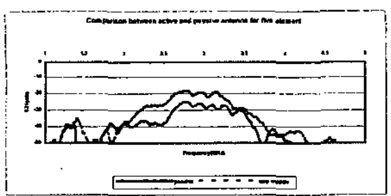


Figure 8. S_{21} response relative to passive

(iv). Radiation pattern characteristic

The radiation is at the broadside direction of the antenna. In the H Plane the radiation patterns remain nearly the same over the entire BW. The radiation pattern is slightly shifted from the broadside direction at frequency 2.90 GHz and 3.05 GHz. In the E Plane the radiation patterns have smaller HPBW compared with the H Plane. At lower frequency 2.55 GHz the cross-polar isolation for E Plane is 20 dB and H Plane is 18 dB. The HPBW for E Plane and H Plane are 70°. The radiation pattern at the middle frequency of 3.05 GHz has a cross polar isolation of 20 dB for E Plane and 18 dB for H Plane. The HPBW at this frequency is 60° for E and H Plane. For highest frequency at 3.50 GHz the cross-polar isolation is 10 dB for E Plane and H Plane. The HPBW at this frequency is 30° for E Plane and 65° for H Plane.

4. CONCLUSION

Integrating an amplifier in front of an array introduces signal gain without reducing bandwidth. Integrating an amplifier in the middle of the feed line appears to offer some potential increase in the bandwidth and introduces additional gain for the array, but it also introduces a negative gain slope vs. frequency. The radiation is at the broadside direction. In the H plane the radiation pattern remain the same over entire bandwidth for both type of integration. However in the E plane the radiation patterns have smaller HPBW compared with the H Plane.

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